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Comparison of subclustering frequency determined from 2D and 3D data

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Abstract. Frequencies of substructure within Abell clusters determined for the same objects using the wavelet analysis for 2-D and 3-D data are similar.

The frequency of substructure occurrence has been determined by several authors, using both various statistical methods and observational data. Sometimes only the positions of galaxies, i.e. 2-D data, have been used, while some papers have been based on the position and redshifts of member galaxies, i.e. 3-D data. The determined frequency changed from below 30% up to 80% of that for Abell clusters with substructures.

The analysis of previous papers suggests that the differences in the determined substructure occurrences are due to the rather different methods of analysis than to the observational data themselves. Therefore, in order to test this hypothesis, in the present paper a direct comparison of the frequency of substructure occurrence is made for 2-D data and 3-D data for the same Abell clusters.

All 43 galaxy clusters in the present work are the result of the objective algorithms for star/galaxy classification applied to scanned photographic plates. There are three sources of our data, but the photographic material came from 48" Schmidt telescopes. Each galaxy within the radius of 1.5 Mpc ($h = 0.75$) from the cluster centre and with magnitude between m_3 and $m_3 + 3$, where m_3 is the magnitude of the third brightest galaxy, was considered as the cluster member. 33 catalogues of Abell clusters were obtained from DSS using FOCAS package, further 4 catalogues were obtained from scans performed in the Rome Observatory (Trevese et al. 1992; Flin et al. 2000), while the remaining 6 catalogues of clusters came from the COSMOS machine at the Royal Observatory in Edinburgh (Krywult, MacGillivray, & Flin 1999).

The existence of the substructures in galaxy clusters has been checked using wavelet analysis. The wavelet technique is a convolution, on a grid of $N \times N$ pixels, between signal $s(r)$ (in our case, the angular positions of galaxies) and analyzing wavelet function $g(r, a)$. In this work we use two-dimensional radial function called the Mexican Hat (Escalera et al. 1992).

For the analysis presented here, the discrete wavelet was computed on a grid of 256×256 pixels for seven scales increasing from $a = 8$ to 64 (in pixel units), namely 8, 11, 16, 22, 32, 45, 64 respectively, which ensure the correctness of the Mexican Hat (Daubechies 1990).

We have modelled the significance of the substructuring detected using the Monte Carlo simulations. For each cluster and each scale a , the wavelet analysis was carried out on a set of 1000 structureless distributions of galaxies containing the same number of points as in the true fields.

We assume that a substructure is real if the probability of random fluctuations is less than 0.005. Furthermore, for each scale a only substructures with more than 4 galaxy members in a circle of radius a are considered.

In order to compare our 2-D data with 3-D data, the Girardi et al. (1997) paper served as a source of information on the subclustering in 3-D data. They used wavelet analysis and performed morphological classification of clusters (Escalera et al. 1994), finding bimodal structure for five clusters (A548, A754, A1736, A3526, A3716) and a complex structure in A2151. Moreover, the existence of substructure was detected in A85, A193, A194, A1060, A1367, A1983, A2063, A2877 and A3667.

In our analysis, substructures were detected in clusters: A151, A426, A548, A754, A1060, A1367, A 1736, A1809, A1983, A2052, A2151, A3128, A3395, A3526 and A3667.

Comparison shows that in some clusters with no subclustering in 2-D, the analysis of 3-D data revealed small substructures, both in size and in the number of members (A85, A193, A194, A2063). In a few cases, the 2-D data showed substructures non-existing in the 3-D data (A151, A1809, A2052).

The differences in the substructure existence in the 2-D and the 3-D data do occur in individual cases. But the frequency of substructure occurrence in 3-D is 31%, while our result, based on the 2-D data, is 34%. At the significance level of 0.05, these numbers are in agreement. So, the frequency of the existence of substructures in Abell clusters determined from 2-D data is a good indicator of subclustering frequency, which allows us to use it for clusters located far away, when the number of galaxies with known redshifts is small.

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